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THE SHRIMP RESOURCES IN THE GULF BETWEEN IRAN AND THE ARABIAN PENINSULA

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PREPARATION OF THIS DOCUMENT

At the request of the Second Session of the Committee on Fisheries, held in 1967, data were collected on the shrimp resources in the Gulf between Iran and the Arabian Peninsula, and an analysis of these data was submitted to the first session of the Indian Ocean Fisheries Commission. The present paper contains a complete revision of the first analysis, incorporating more recent data. This paper was used as a background document for the meeting of the IOFC Working Party on Stock Assessment, held in Rome in October 1969.

The paper refers to the shrimp stocks in the various areas of the Gulf and does not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

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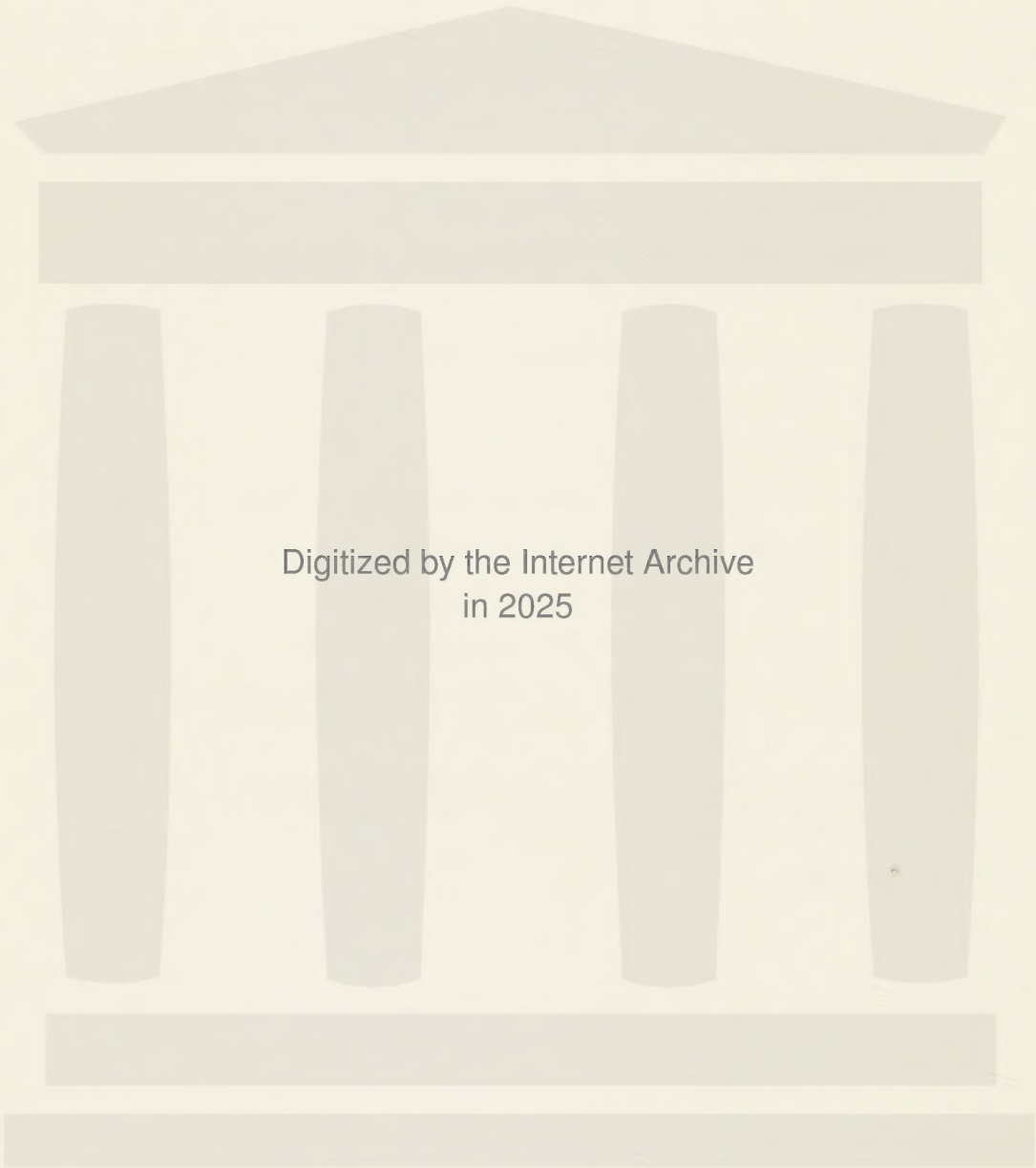

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1. INTRODUCTION

The shrimp resources in the Gulf between Iran and the Arabian Peninsula, in this report referred to as "the Gulf", have been subject to a rapid increased exploitation in the last ten years, and various countries in the area have expressed their concern about the possible detrimental effects of an overexpansion of this fishery.

In order to make an analysis of the state of the shrimp resources, statistical and other information has been collected from the Governments and the fishing companies in the area, and a preliminary report on the findings was submitted to the first session of the Indian Ocean Fishery Commission (Boerema and Job 1968). The present paper is a revision of, and supersedes, that document, and contains a new analysis, including the catch figures for 1968.

2. GENERAL CHARACTERISTICS OF THE GULF

The Gulf extends over about 500 mi in a northwest direction from the Hormuz Strait, and covers an area of about 70,000 mi^2 or 240,000 km^2. The Gulf is shallow, slowly deepening towards the Hormuz Strait, the depth rarely exceeding 90 m, in the north-western half not exceeding 70 m. The Iranian side is somewhat deeper than the waters off Saudi Arabia but on both sides there are very shallow areas along the shores. Vast bottom areas, in particular in the central and the north-western part of the Gulf, are covered with mud, with large mud flats in the Shatt al Arab region in the extreme north. The bottom along the main part of the Iranian coast is plain and suitable for trawling. The bottom along the coast of the Arabian peninsula, however, is rough with sand banks and coral reefs, and only limited areas suitable for trawling with shrimp trawls.

The salinity of the water in the Gulf is high (about 40-41‰), due to the strong evaporation; the surface water temperature ranges from about 15°C in winter in the colder part of the Gulf to 36°C in summer in the warmest areas (Blegvad 1944).

3. METHODS USED IN THE STUDY OF THE STATE OF THE STOCKS

In order to indicate the methods used in the analysis of the shrimp stocks it may be useful first to give a very short summary of the principles involved in the exploitation of renewable natural resources.

When a fishery starts on a hitherto unexploited resource, (i.e. a shrimp stock) the total landings will at first rise more or less in proportion to the fishing effort (number of boats or their total fishing capacity). The observed catch per boat may initially increase due to improvements in the efficiency of the boats and gear, increasing knowledge of the fishing grounds and of the movements of the shrimp, etc. However, as fishing develops and the fishing effort reaches substantial levels, the catch per unit of effort (i.e. the catch of a standard boat for a standard time fishing) will decrease because the fishery affects the shrimp stock.

Of a given number of young shrimp reaching catchable size a more intensive fishery takes a greater fraction during the lifetime of those shrimp; it exerts a higher fishing mortality. By taking a greater part of the young shrimp it leaves fewer shrimp to grow to a larger size. This results in a smaller total number of shrimp in the sea, in particular of the larger sizes, for a given number of recruits. Thus, if fishing becomes more intensive, it causes (i) a decrease in the catch per unit of fishing effort; (ii) an increase in the total numbers caught; and (iii) a decrease in the average size of the shrimp caught.

As long as the total amount of fishing, from a given number of recruits, is not too great, the increase in total numbers caught will outweigh the decline in the average size of the shrimp and the total catch by weight will increase; but this difference becomes smaller with increasing amount of fishing and the amount of fishing may reach a level where at further increases in fishing, the increase in numbers caught becomes less important than the decline in their average weight so that the total catch by weight decreases.

The above conclusions all refer to the catch obtained from a given number of recruits, young shrimp, during their lifetime. However, the reduction in the number of large shrimp will also reduce the number of eggs produced. This might result in a smaller number of offspring, and this would mean that in the following years smaller numbers of shrimp would be caught. If this is the case, increased fishing beyond a certain level might not lead to

an increase in the total numbers caught as explained above, but in a decrease. Investigations of shrimp stocks in other areas, however, have in most cases not detected any such observable stock-recruitment relationship. Apparently the relatively moderate level of abundance of adult shrimp such as occur in most of the fished stocks is normally sufficient to maintain the average level of recruitment of young shrimps although undoubtedly recruitment will decrease at extremely low levels of abundance of adult shrimp.

In addition to the possible effects of changes in adult stock, changes in recruitment can also be caused by natural environmental factors. It has, for example, been observed that differences in rainfall can influence the recruitment of shrimp species with larval stages in the coastal brackish water areas, and in fact annual fluctuations in recruitment are commonly observed in most of the studied marine fish and shrimp. A decrease in recruitment due to natural factors can be expected to result in a decrease in total catch and in catch per unit effort, and also in total numbers caught, but not in a change in catch per unit effort and total numbers caught "per unit of recruitment", nor in the percentage of large shrimp in the catch.

An increase in the natural mortality rate, due to natural factors, would cause changes in the catch of the same nature as those caused by fishing, but no indication of such increases has been found in studies on shrimp fishing in other areas, and they would probably occur to any important extent only in very exceptional natural conditions which would be clearly recognisable.

Thus, a study of the changes in total catch by weight, in the catch by weight per unit fishing effort, in the total numbers of shrimp caught, in the percentage of large shrimp in the catch, and in the magnitude of the recruitment, which have occurred following an expansion of fishing enables conclusions to be drawn on the state of exploitation of the shrimp stocks. Such data can all be derived from the records of the commercial fishing companies in the Gulf areas and those records have to some extent been made available for the present investigations.

Other useful data for a study of the state of exploitation of living marine resources can be obtained from biological studies of the species, including those of growth rates, mortality rates, age-compositions, migrations, and from exploratory fishing surveys, including for some species also echo sounder surveys etc. The best and most reliable results are usually obtained when various of these methods are combined. No biological and survey data of the type needed for these studies are, however, available on the shrimp resources in the Gulf, and the present report is wholly based on the collected statistical information.

4. THE SHRIMP FISHERY

4.1 Development of the shrimp fleet

The industrial shrimp fishery started in about 1959, both in Iran and in Kuwait. In the first years the activities remained at a modest level, and in 1962 the Iranian company finished its shrimp operations. From 1963, however, the industry developed faster. A company in Saudi Arabia started operating, the fleets increased, two more Kuwaiti companies joined in 1965, and at the beginning of 1969 the total number of companies actively participating in the fishery included one based in Iran, one in Iraq, four in Kuwait, two in Saudi Arabia, one in Bahrain, and one in Qatar. In addition to these companies, ships of foreign nationality have fished in the Gulf, usually under contract with one of the national companies, and in some recent years some USSR vessels also took part in the shrimp fishery.

Table 1 shows the number of commercial shrimp vessels in the Gulf at the beginning of each calendar year. Data have been obtained from most of the existing companies, and in addition also from information in unpublished reports (Halig 1961, Johnson 1961), internal FAO travel reports etc., and information in Commercial Fisheries Review. Information from different sources showed different figures for the number of trawlers in the first years of the industry. In these cases the lowest and highest figures are both included in the table. The number of ships is shown to have increased continuously from 1963 to 1968, and thereafter to have remained nearly stable.

Table 1 - Number of industrial shrimp trawlers operating by country:

Date 1 Jan	Country							
	Iran	Iraq	Kuwait	Saudi Arabia	Bahrain	Qatar	USSR	Total
1959	2-3	-	-	-	-	-		2-3
1960	9	-	2-8	-	-	-		11-17
1961	9-12	-	2-8	-	-	-		11-20
1962	9-12	-	6-8	-	-	-		15-20
1963	-	-	14	2	-	-		16
1964	-	-	18	7	-	-		25
1965	-	-	30	12(?)	-	-		42
1966	-	-	52	16	-	-	?	68
1967	-	-	71	25	-	-	?	96
1968	15	2	69	25	8	3	3	125
1969	15	?	70?	25?	8	3	-	125?

Note to Table 1 :

Data on Saudi Arabia not precise for the years before 1966. In addition to the trawlers included in the table, some trawlers of foreign nationality have fished in the Gulf at different times, usually under contract with one of the national companies and delivering their catch to these companies. Although precise and complete details have not become available for all cases, it can be taken that this normally did not concern more than 3 or 4 boats in any one year (Japanese, Greek and Italian ships which have worked or are working in the Gulf some into this category). Part of the Kuwait fleet has been fishing in waters off the Iranian coast, and in 1968 also in the waters along the Arabian peninsula.

4.2 Total landings

Data on the quantities landed were obtained from nearly all the existing fishing companies, but data of one or two existing companies had not become available at the time of preparation of this report.

Until 1965, by far the greatest part of the commercial shrimp catches were exported to USA, but in the last few years the exports to Japan increased. Although some quantities were also exported to European countries, the combined imports into USA and Japan will give a fair picture of the development of the industry. These data, together with those of the majority of the fishing companies, and some further information in reports and fisheries journals, allow to make a reasonable estimate of the commercial shrimp landings in the period under investigation. The data are shown in Table 2.

Table 2 - Shrimp landings from the Gulf by the industrial shrimp fisheries (in '000 lb, tails only).

Year	Data from imports in USA and Japan*					Total	Data from fishing Companies**	Estimate of total landings
	Iran	Kuwait	Saudi Arabia	Bahrain	Others			
1959	739	-	-	-	-	739		800
1960	1,226	146	77	-	-	1,449		1,500
1961	1,953	194	-	-	-	2,147		2,200
1962	724	415	-	51	-	1,190		1,200
1963	87	3,728	100	-	30	3,945		4,000
1964	682	5,358	430	-	-	6,470		7,500
1965	6,801	5,818	1,201	-	61	13,881	13,508	14,800
1966	9,230	5,744	3,471	206	86	18,737	15,445	20,000
1967	2,219	8,803	3,078	1,664	-	15,764	14,052	18,000
1968	2,665	9,276	3,952	4,952	113	20,958	17,700	22,000

Note to Table 2:

A varying proportion of the shrimp reported as imported from the countries named has been caught in waters off other countries, e.g. part of the shrimp imported from Kuwait has been caught in waters off Iran and Saudi Arabia.

**Saudi Arabia and USSR not included. Some data of years before 1965 available but not presented because they refer to data from one or two companies only. These data are used, however, in the estimate of the last column.

The table demonstrates the considerable rise in the shrimp landings in the period 1962-1966, whereafter the catches in 1967 were somewhat lower than in 1966. In 1968 the total catches were again higher than ever before.

In addition to the landings by the modern commercial shrimp fishery, a certain amount of shrimp has been caught in the traditional inshore fisheries which are carried out and have some importance in many of the coastal areas. Although it is difficult to estimate the quantities involved, there are some indications that they amount at least to a few million pounds of whole shrimp annually. It may be assumed that this quantity has remained more or less stable over the period under investigation, and thus will not have affected the trend in the landings to any extent.

One development, however, needs special mention. Keyvanfar (1966), in an internal report to the Southern Fisheries Company (also named Persion Gulf Fisheries Company) in Iran, mentions that the local fishermen in the region of the Hormuz Strait who own bigger type ships have been following the examples of the foreign fishermen and started trawling for shrimp in this area in 1965, and particularly in 1966. He estimates that the 23 motor vessels involved caught about 1,500 tons of, presumably whole, shrimps, equivalent to about 2 million lb of shrimp tails.

It can thus be estimated that the total shrimp catch in the last few years has been the order of 22-26 million lb of shrimp tails, equivalent to roughly 17-20,000 tons of whole shrimp.

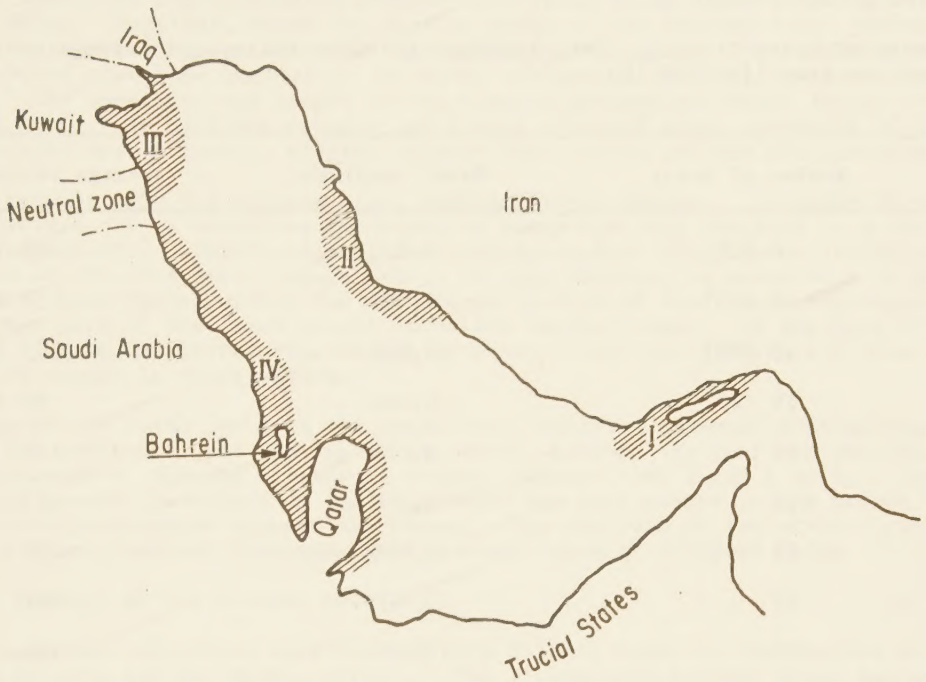

Figure 1. Main areas of commercial shrimp fishing in the Gulf between Iran and Arabian Peninsula

4.3 Catch per boat

In order to calculate the catch per boat, the average number of boats working in each year has been taken as the mean of the number at the beginning and the end of each year. The results are given in Table 3.

Table 3 - Number of boats fishing, total landings by these boats, and average catch per boat per year (in '000 lb).

Year	Number of boats	Total landings	Average catch per boat
1959	6 (10)	800	133 (80)
1960	11 (18)	1,500	136 (83)
1961	13 (20)	2,200	169 (110)
1962	15 (18)	1,200	80 (67)
1963	21	4,000	190
1964	33	7,500	227
1965	55	14,800	260
1966	82	20,000	244
1967	110	18,000	164
1968	125	22,000	176

The table shows that the catch per boat has risen steadily (with the exception of 1962 when the Iranian company stopped operations) until 1965, and thereafter declined. This is apparent for both the low and the high estimates of the number of boats in the first years.

The rise in the catch per boat in the first period was probably due to an increase in the average efficiency of the vessels and their operations, gradually increasing knowledge of the fishing grounds, etc. The decline in these figures of the last three years, however, is likely to reflect a real decrease in the shrimp population either due to the fishery itself, or to natural causes.

4.4 The species composition of the shrimp catches

The shrimp caught in most areas in the Gulf consist for more than 90% of Penaeus semisulcatus (Hall 1966, White personal communication, Keyvanfar personal communication), with a few per cent of other species.

Some recent observations off Kuwait suggest that the species composition here is different, with at least two major species in the landings, probably Penaeus semisulcatus and another small species of shrimp.

4.5 The catches by area and by season

Roughly, four main areas for shrimp fishing can be distinguished:

the Hormuz Strait on the Iranian side (I) ;
the Iranian coast in the Bushehre-Dayer region (II) ;

the coast off Kuwait and Iraq (III) ;
and a number of isolated areas along the coast of Saudi Arabia, Bahrain and Qatar (IV) (see fig.1).

In the beginning the most important fishing grounds were those in the Hormuz Strait. Later, in about 1962, the Bushehre-Dayer grounds were found which are now the major fishing grounds in the Gulf. Together, these two fishing areas on the Iranian coast produced about half the total shrimp production in the Gulf in the last few years. The grounds off Kuwait and Iraq contributed about one quarter of the total production in 1966, but less than one-fifth in 1967. The remainder was caught on the fishing grounds off Saudi Arabia and Bahrain, and in the open Gulf. In 1968 the grounds off Kuwait produced about one-sixth of the total catch, the remainder nearly equally divided between the Iranian and the Arabian side.

Thus, the catches from the various areas show different trends. In order to obtain a more complete picture, it is therefore important to study not only the Gulf as a whole, but also the areas separately. Unfortunately, detailed data about the grounds fished are only recorded by some of the more recent companies. It can, however, be taken that in general the companies will have fished within the territorial waters of their home countries, with eventually a minor part of the catch caught in waters farther away. In the case of companies with licence to fish in the territorial waters of other countries, details are usually available on the quantities caught in those waters.

The figures of the catch per boat per month show important seasonal fluctuations. The differences in the catch per boat per day or per month, between the poor periods and the peak months, are considerable, showing a ratio of roughly between 1 to 3 and 1 to 5. Usually the low catches occur around the middle of the year, with the peak months in the second half of the year, but there are differences between the areas. The analysis of the shrimp catches by area should also take these seasonal phenomena into account, as will be shown below.

4.5.1 The fishery on the Iranian coast

It has already been mentioned that the two main fishing areas on the Iranian coast are the Bushehre-Dayer area and the Hormuz Strait. The fleets move between these two areas depending on the catch rates, so that a more or less seasonal pattern develops, the Hormuz Strait having been fished in particular in November-December, in the last few years. The available data on the areas fished are, however, not sufficiently detailed to enable an analysis of the Hormuz Strait fishery separately. Because the greater part of the catch is caught in the Bushehre-Dayer area, the trends in the total catches will be fairly representative for the shrimp fishery in that area.

Figure 2 demonstrates the total catch, the number of boats operating in each year, and the average catch per boat per year. The fleet increased until 1967, as happened in the fishery in the whole of the Gulf. After an initial period of low catches, mainly in the Hormuz Strait, fishing in the Bushehre area was started in 1963. The total catch increased to a maximum in 1965, and decreased thereafter. The catch per boat per year was high in 1963 and 1964, rose to a maximum in 1965 and decreased thereafter to a level which was substantially lower than in any other year since 1963.

In order to analyse whether these changes have been due to fishing, or to natural fluctuations in the shrimp stocks, it is first necessary to study the seasonal fluctuations in the catches.

Figure 3 gives a picture of the catch in weight for each month averaged over the last three years (1966-1968). This graph shows that the catches decreased in the first half of the year, to a very deep low in June, then suddenly increased very much in July, reached a peak in August-September, whereafter they declined again. This graph exaggerates the real changes in the density of the shrimp stocks, because it represents the total catches made each month. In the period of low catches the fleet also has spent less time fishing, either by less boats going out, or by the boats having less actual fishing days during these months, and thus the differences are partly caused by variations in amount of fishing. Although, therefore, a limited number of available data on catch per boat per day fishing show less extreme variations, the general picture remains similar (see the broken line in fig.3).

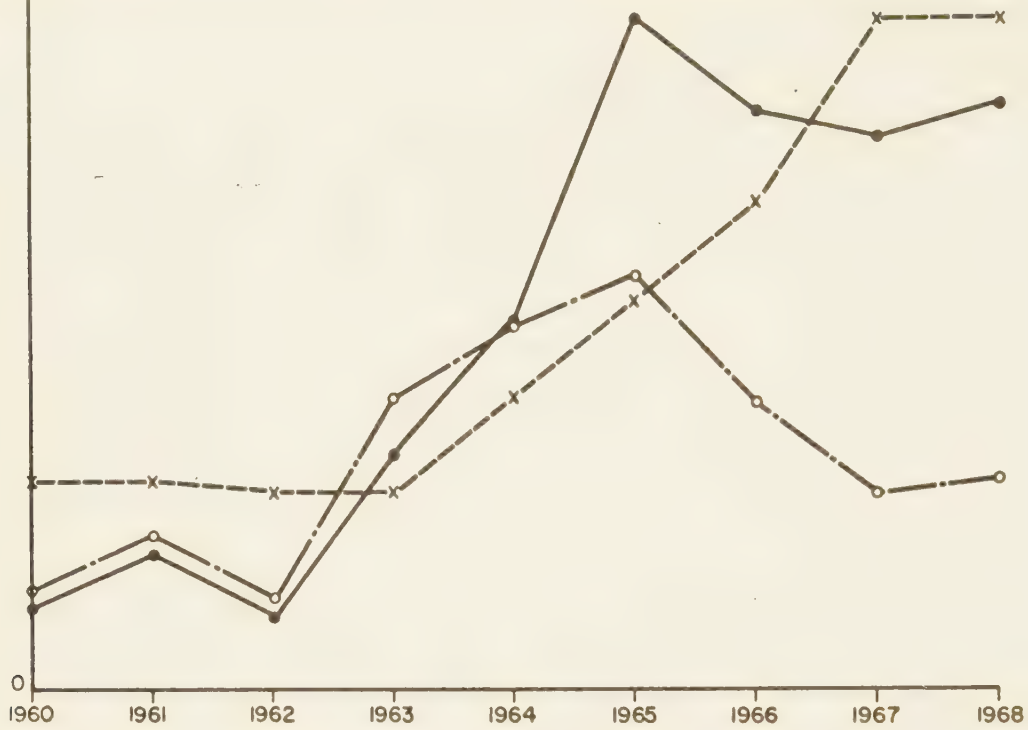

Figure 2. Shrimp fishery off Iran. Number of boats (x---x), total catch (●——●) and catch per boat (○·—○), per calendar year

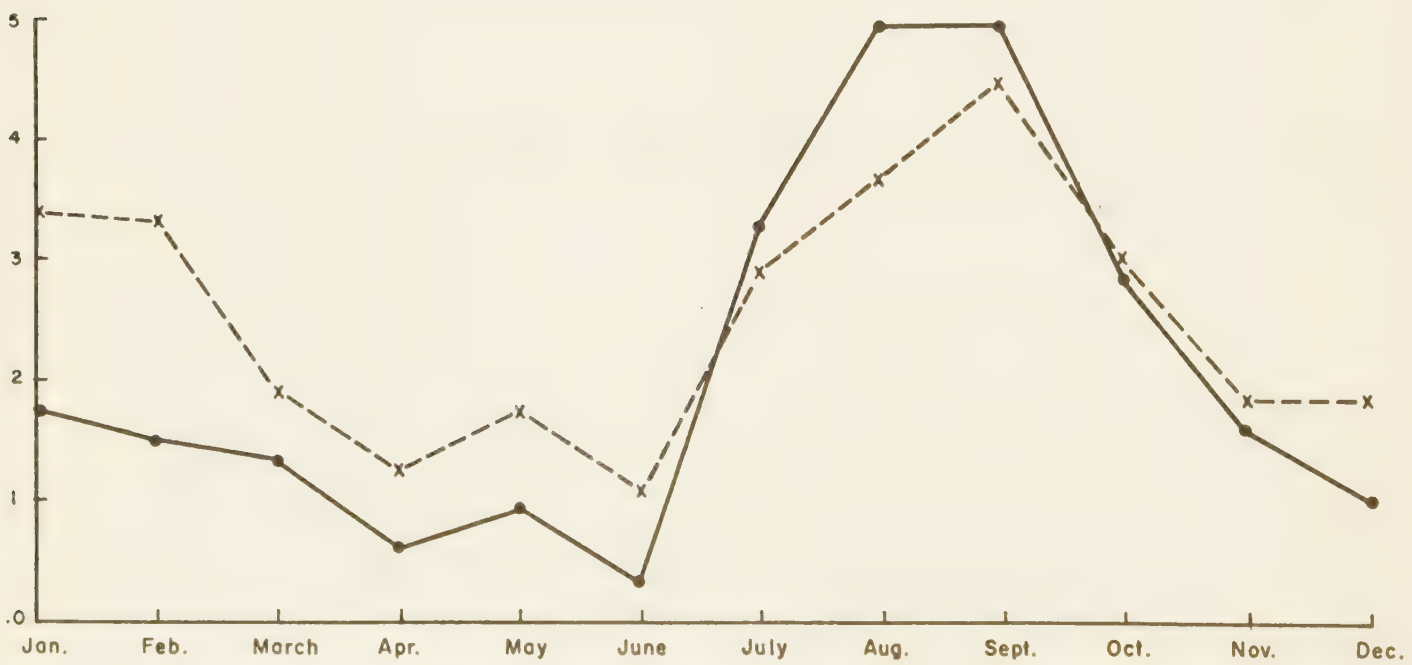

Figure 3. Seasonal fluctuations in the catches of shrimp off Iran.

●——● monthly total catch (average of 1966 - 68)

x---x monthly catch per boat per day fishing (data from 1966 - 67)

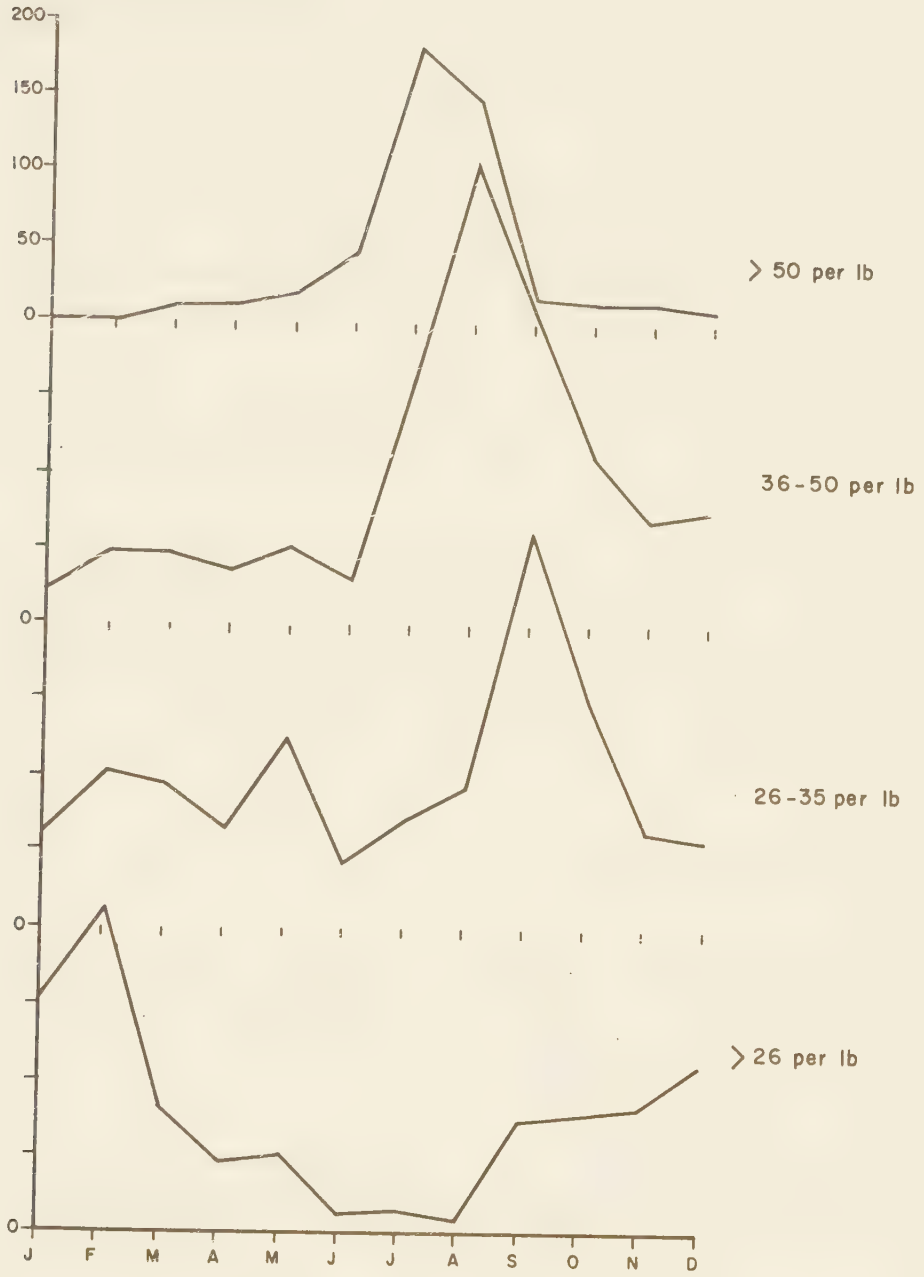

Figure 4. Shrimp fishery off Iran.
Monthly average catch by weight, by size category, per boat - day, 1966 -68.

This seasonal fluctuation is not only apparent in the total catch, but also in the size composition of the catches. Figure 4 demonstrates the monthly figures of catch per boat/day of shrimp of various sizes, obtained from the detailed statistics of the landings by weight per commercial size grading (average of 1966-1968). This figure shows that small shrimp (more than 50 per lb) is practically absent from the landings in the winter months. Small quantities appear in spring, and in June the catches of this group rise to reach a high peak in July and August. Thereafter the catches fall to a low level again. The catches of shrimp of somewhat larger size (36-50 lb) show a similar peak in August with fairly low catches throughout the greater part of the year. The next size group (26-35 lb) has its peak in September, and the largest shrimp (less than 26 per lb) around December-February. Although the variation in the catches does not only depend on the changes in the size distribution in the shrimp stock, but also on the spatial distribution of the various sizes and of the fishing fleet, the regularity of the phenomenon in the various years indicates that recruitment of the young shrimp to the fishery takes place mainly in July and August, and that the majority of this shrimp grows very rapidly to reach the size of 35-50 per lb in about August, of 26-35 per lb in about September and of less than 26 per lb by about the end of December. The curve of the largest shrimp does suggest that many of the large shrimp have disappeared by next July.

Thus, the catch of one calendar year consists of middle size and big shrimp of last year's recruitment, caught predominantly in the first half of the year, and of small and middle sized shrimp of the same year's recruitment, caught mainly in the second half of the year, whereas the catch in the period from July in one year till June next year consists predominantly of shrimp of one recruit class, including perhaps some old shrimp from the previous and also some young shrimp from next year's recruitment.

In order to analyse the effects of fishing on the catch of each of the recruit classes, the data have therefore been grouped in periods July-June. The data on catch and effort are shown in fig. 5. The figures for 1965-66 are not complete, because data for July and August 1965 are lacking. Estimates for the whole season 1965-66 are indicated by the connecting dotted lines. Thus, the catches of the seasons 1965-66 till 1967-68, being the catches of the recruit classes of the years 1965, 1966 and 1967 respectively, have fluctuated irregularly between 8 and 10 million lb. At the same time, the total fishing effort, measured as the sum of the number of months each boat has been fishing (called boat-months), has increased, and the catch per boat-month was substantially lower in the last two seasons than it was in season 1965-66. In general, these results confirm the picture given in fig. 2 for the last three years.

Further information is obtained if the catch of each recruit class is separated into the catch made during the first six months after recruitment (in the months July-December) and in the second six months (January-June).

Figure 6 shows that the catches during the first six months of each recruit class have increased greatly from 1965 to 1967 (inspection of the total catches in 1964 suggest that those of the recruit class 1964 caught in July-December of that year will have been substantially below those of 1965, so that the increase of these catches probably covers the whole period 1964-1967). At the same time, the catches of the same recruit classes during the second six months of their availability in the fishery (January to June) have shown a considerable decrease in the period 1964-1966.

Figure 2 shows the great increase in the number of fishing vessels engaged in the fishery in these years, and the number of boat-months in January-July rose from 172 in 1965 to over 200 in 1966 and 1967. Hence, the decrease in the catches in January-July of the successive years is not due to a decrease in fishing in these months, but rather to a decrease in the stocks.

These data, therefore, indicate that the increase in the fishing fleet, and thus in the fishing effort exerted on the stocks, has led to larger total catches in the first part of the fishing season, from July onward, when many small shrimp enter the fishery, with the result that less and less shrimp remained to supply the stocks of middle and large sized shrimp in January-June.

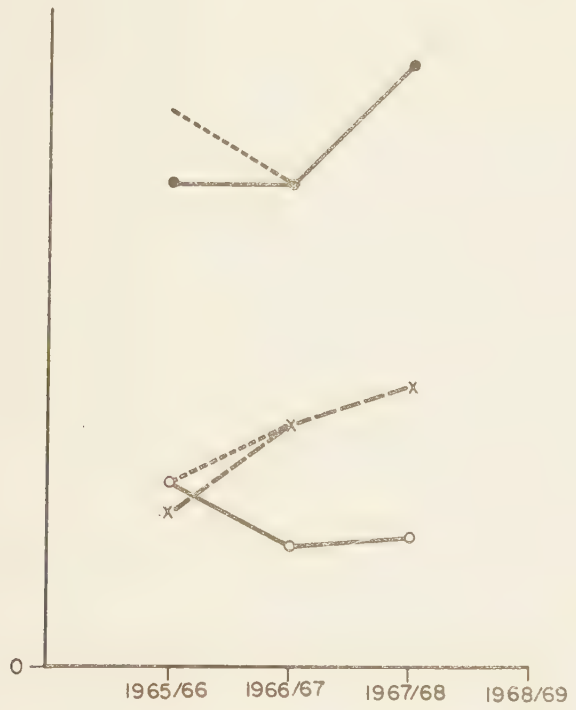

Figure 5.

Shrimp fishery off Iran:
Total catch (●——●)
No. of boat-months (x– – –x)
and catch per boat-month (○–·–○)
in the periods July-June of
successive years.
(Seasons 1961-6 incomplete,
small dotted lines show
estimated figure for complete
season 1965-6)

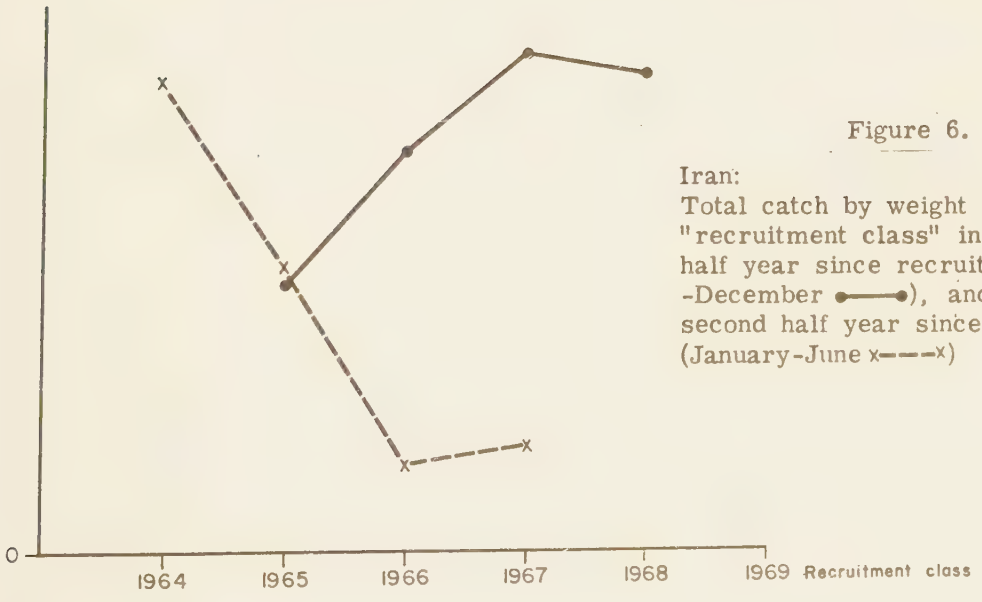

Figure 6.

Iran:
Total catch by weight of each
"recruitment class" in the first
half year since recruitment(July-
-December ●——●), and in the
second half year since recruitment
(January-June x– – –x)

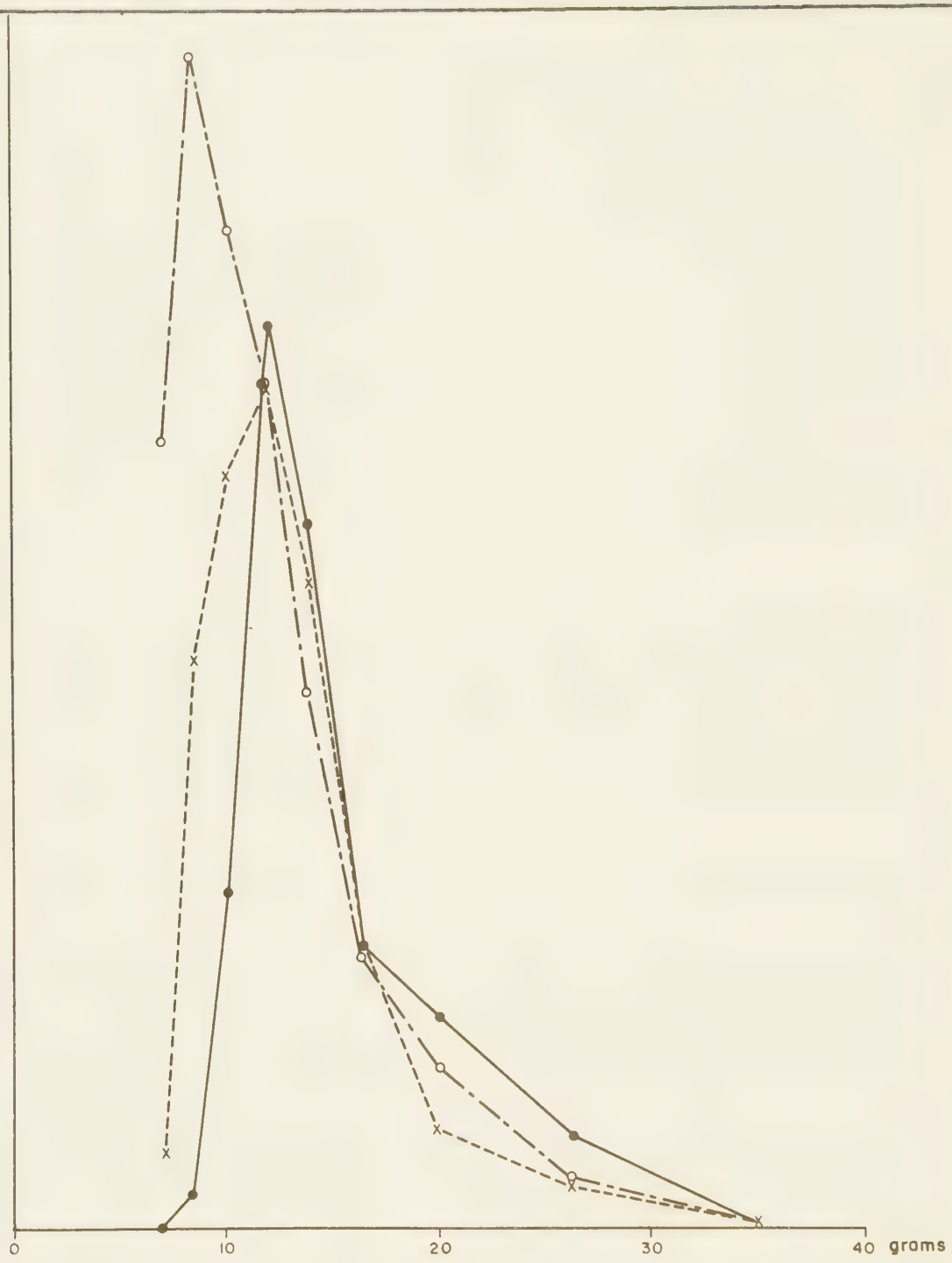

Figure 7. Size composition (number for each gr. tail weight) of the shrimp landed from the Iran coast.

Sept. 65 - June 66
July 66 - June 67
July 67 - June 68

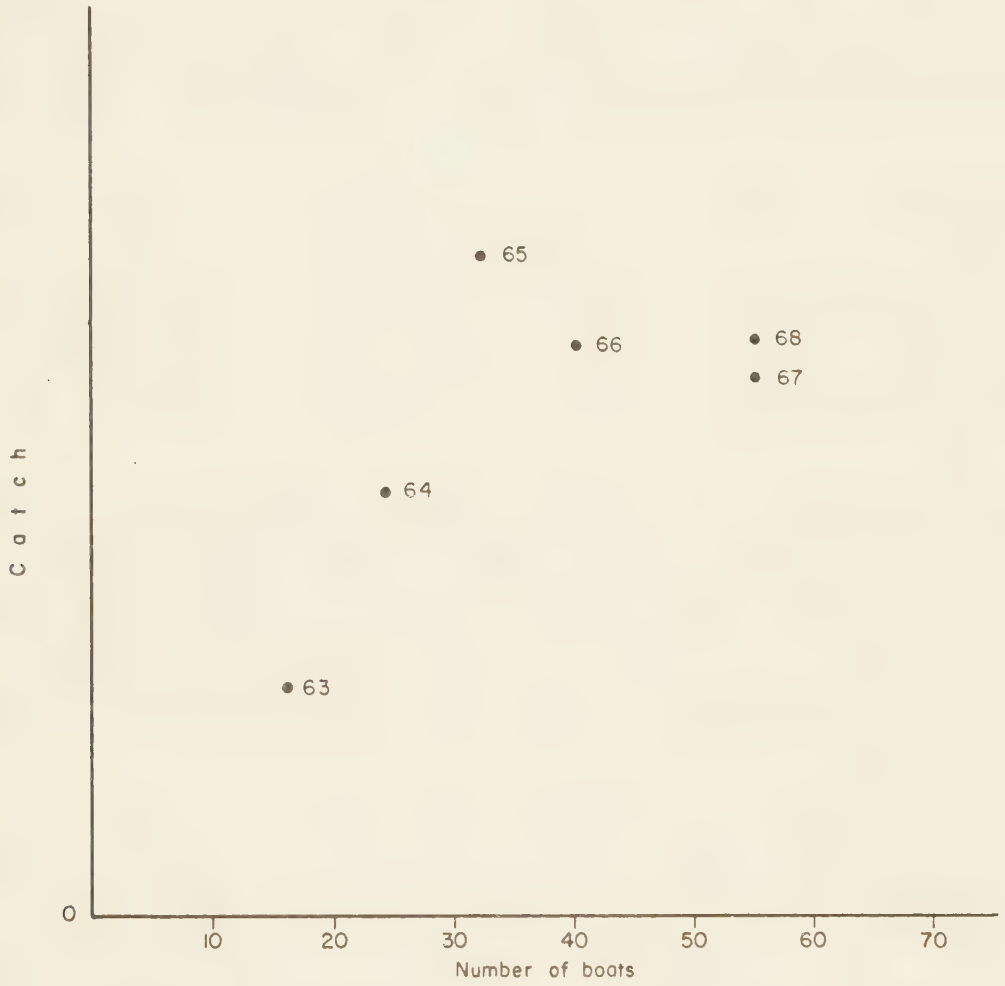

Figure 8. Shrimp catch per year at different levels of fleet size, in the area off the Iranian coast.

The increase in the July-December catches has more or less balanced the decrease in the January-June catches, and thus the total catch by weight of each recruit class has fluctuated about roughly the same level in the last years. The extra high catches in the calendar years 1965 and 1966, as shown in fig. 2, were due to the fact that the catches in calendar year 1965 consisted of the January-June catches of recruit class 1964 and the July-December catches of recruit class 1965, and in the calendar year 1966 of the January-June catches of the recruit class 1965 and the July-December catches of recruit class 1966. Inspection of fig. 6 will show that these sums give a higher figure than the actual catch of each recruit class.

A possibility to estimate the catches by numbers is given by the detailed statistics of the landings by weight by commercial size grading (i.e. 11-15 per lb, 16-20 per lb etc.).

Figure 7 gives a picture of the numbers caught of each size in the periods July-June. In plotting these numbers, the range covered by each size group has been taken into account. Only the catches in July 1966-June 1967, and in July 1967-June 1968, representing the catches of the recruit classes 1966 and 1967 respectively, are fully represented in the graphs. The graph for 1965-66 is incomplete, because no details were available for July and August 1965. Inspection of fig. 3 shows that for this reason the small shrimp are considerably under-represented in the graph of 1965-66, and that even the middle sized shrimp is not completely included.

If the incompleteness of the graph of season 1965-66 is taken into account, it not only appears that the landings of this season contained more big shrimp, but it would also seem that the slope of the right-hand side of the curve is less steep than that for the seasons 1966-67 and 1967-68, which would be in agreement with the lower fishing effort in 1965-66. Also, the slope of the curve for season 1967-68 seems less steep than for season 1966-67, although partly they run very close. This would be in agreement with the data on the total number of boats in the fishery, but not with the available data on boat-months. The data on the total number of days fished by all boats together (number of boat-days) are incomplete, but suggest that it could well be that the real effort in 1967-68 has been below that in 1966-67. Thus, the indications obtained from the right-hand side of the curves are in general agreement with the previous conclusions on the effects of fishing obtained from the half-yearly catches.

Turning to the left-hand side of the curves, it has been stated that this part of the 1965-66 curve does not represent the total catches of small shrimp. It seems likely that, if the July and August catches had been included, the line would have run at about the level of the one for 1966-67, but it seems very unlikely that it would have reached the level of 1967-68. Anyway, the curves show that there has been a very considerable increase in the landings of the small shrimp in 1967-68 as compared with 1966-67. The available data for the season 1968-69 show that in this season the landings of small shrimp were at the same level as in 1967-68. This difference is far too great to be caused by the observed increase in fishing effort only. There may be two possible causes. Firstly, the small shrimp may also have been caught in the earlier years, but have been discarded. Unfortunately, no data about discards are available. If this has happened, then the quantities of shrimp actually caught of the recruit classes 1966 and before has been higher than the figures landed as given in this report, and in that case, the increased fishing after 1966 may well have been the cause of some decline in the total catches. The second possibility is that the fishery in the earlier years avoided the areas where the small shrimps were predominant. In that case, this small shrimp had a chance to grow to a bigger size and that may have contributed to relatively high landings of the recruit classes 1964-66 as compared with the later years.

Taking all the evidence discussed above together, the analysis has shown that the fishing effort on the presently exploited shrimp stocks on the Iranian coast has risen to a level at which it greatly affects these stocks, or in other words, that the present fishing mortality forms a substantial part of the total mortality of the shrimp.

This is also shown in fig. 8 which gives the relation between total effort (in number of boats) and total catch.

Figure 9. Shrimp fishery off Kuwait. Number of boats (x---x), total catch (●——●) and catch per boat (○-·-○) per calendar year

Figure 10. Kuwait: Seasonal fluctuations in the total catches, by weight, of shrimp. Average 1966 - 68.

The data indicate that further increase in the fishing fleet will not substantially increase the total catches, and that the present level may even already have surpassed the level giving maximum yield. At the same time such increase would cause a further decrease in the average catch per boat, and it would also lead to a further decrease in the number of shrimp surviving to the larger sizes, which would mean that the number of shrimp reaching maturity might be reduced to below a level necessary to maintain sufficient offspring. The data suggest that at the present way of fishing the maximum yield of the stocks is of the order of between 9 and 10 million lb of shrimp tails per recruit class (and hence, on the average, per year), with some fluctuations around this average depending on the variations if recruitment is due to natural circumstances. The observations since 1965 suggest that in this period the fluctuations were within 1 million lb above or below this average.

It is possible that protection of the small shrimp will lead to a higher total yield than that mentioned above. This will be discussed in section 5.

4.5.2 The fishery off the coast of Kuwait

Shrimp fishing off Kuwait commenced at a low level at the beginning of the shrimp fishery in the Gulf, but it expanded considerably in the second half of 1965, when some new companies started their activities. Figure 9 shows estimates of the total catch, of the number of boats operating each year, and the calculated average catch per boat per year, since 1965. The fleet increased from 1965 to 1968. In 1968, however, part of the fleet fished part-time in other waters. The figure for the number of boats fishing off Kuwait makes allowance for this. A better estimate of the effort is, probably, the sum of the number of months each boat has fished in Kuwait waters. This figure increased till 1967 and decreased somewhat in 1968. The figures of total catch, average catch per boat per year, and average catch per boat per month, all are high in 1966, low in 1967 and high or moderate in 1968.

The average seasonal fluctuation in the catches is given in figure 10. This picture differs in some respects from the seasonal fluctuation in the catches off Iran. The main differences are the low catches in December-January, the moderate peak in March and April and the later start of the rise to the high peak in the second half of the year in the Kuwait catches.

The seasonal fluctuations in the catches of the various sizes of shrimp are shown in figure 11. The months June-October give a picture of changes in the catches which are very similar to those of the catches off Iran (fig. 3). The peak in the catches of the small shrimp (51-60 per lb) appears in August, and the modes in the curves of the following size groups appear successively later. In each group the maximum occurs about half a month later than off Iran. In November and in particular in December, however, the catches of all groups above 36 per lb drop to a very low level, and rise again in the beginning of the next year. This is not apparent in the Iran graphs. It should be rememberd, however, that the Iran data refer mainly to the fishery in the Bushehre-Dayer area, but that in November-December the catches in this area drop to a low level and at least part of the fleet moves to the Hormuz Strait. Hence, the actual catches in the Bushehre-Dayer area are lower than shown in the graphs in November and December which are based on all Iran catches. Thus it seems that both in that area and off Kuwait the catchability of the shrimp in November and in particular in December is low, but thereafter increases again. The drop in the catches of large shrimp (26-35 and less than 25 per lb) off Kuwait between March and April is steeper than off Iran, and is too steep to be due to fishing mortality only. Apparently, in this case too the steep decline is to some extent due to a decrease in catchability.

One marked difference between the catches off Iran and off Kuwait is the amount of small shrimp caught, of more than 60 per lb. Whereas off Iran the catch of shrimp of more than 60 per lb reached about half the amount of that between 51 and 60 per lb, and was caught predominantly in July and August, the catch of the shrimp of less than 60 per lb off Kuwait rose to more than twice the amount of the 51-60 per lb shrimp. Furthermore these small shrimps were mainly caught in the months April-June, and contained very small sizes, down to 90-110 per lb.

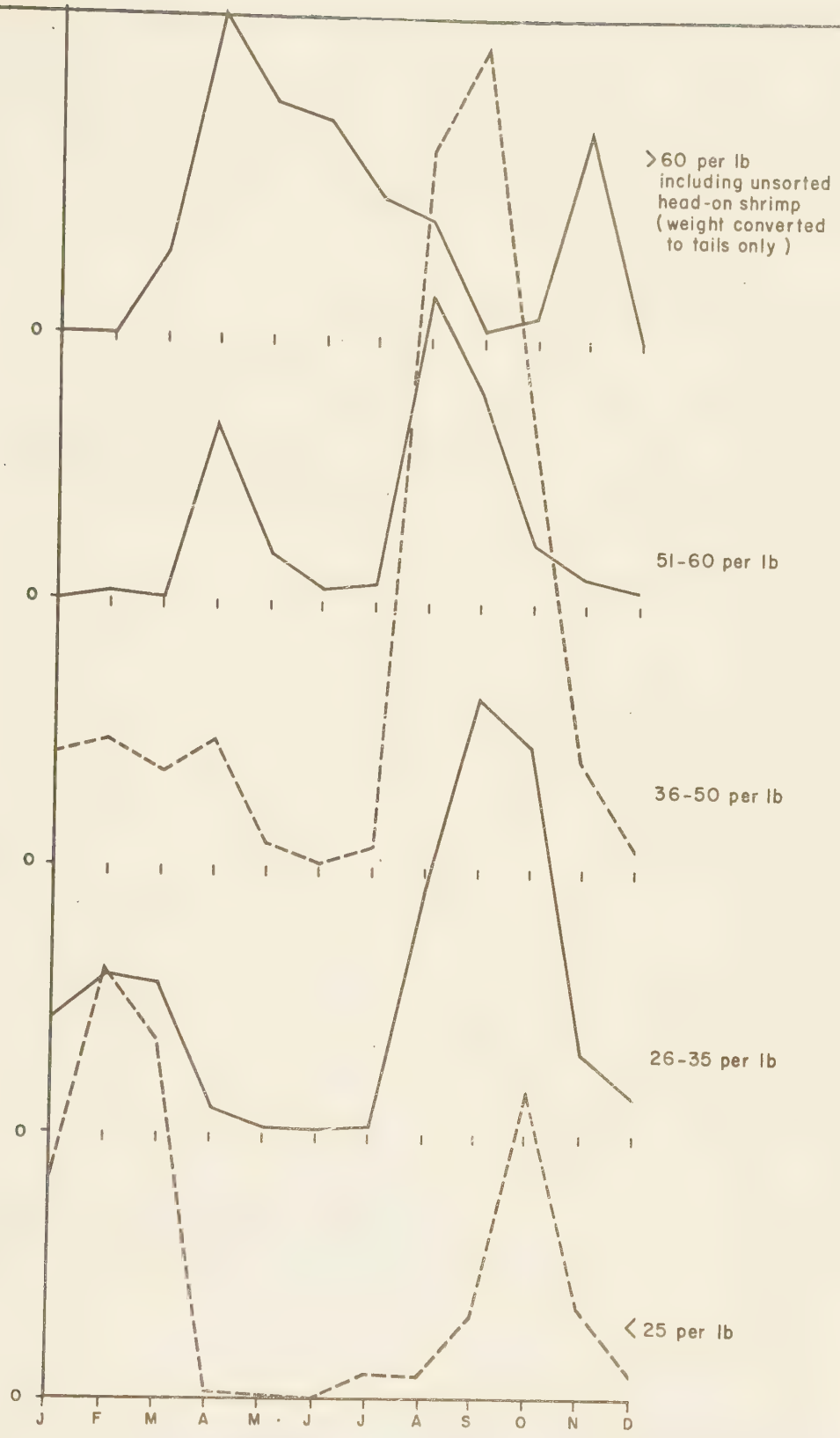

Figure 11. Kuwait: Shrimp
Average monthly catch per size category, by weight, per boat. Average 1966 - 68.

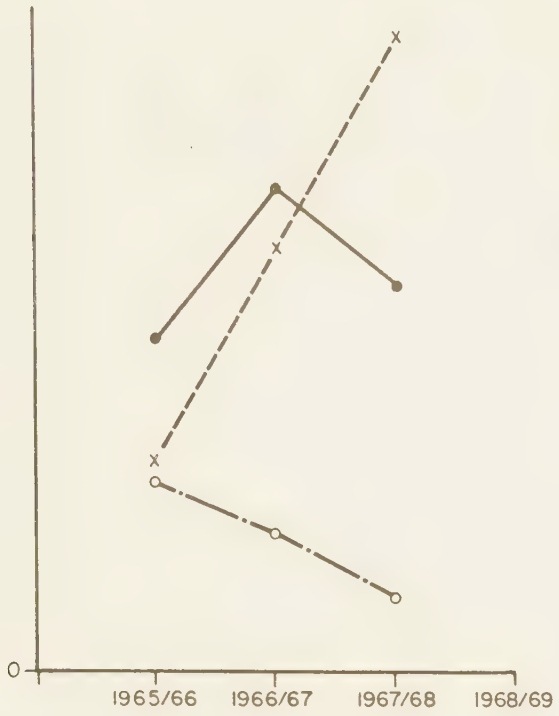

Figure 12.

Kuwait:
Total catch (●——●)
no. of boats-months (x– – –x)
and catch per boat per month (○—·—○)
per season July-March
(The data for 1968 include some
catches and boat-months from the
Saudi-Arabian coast)

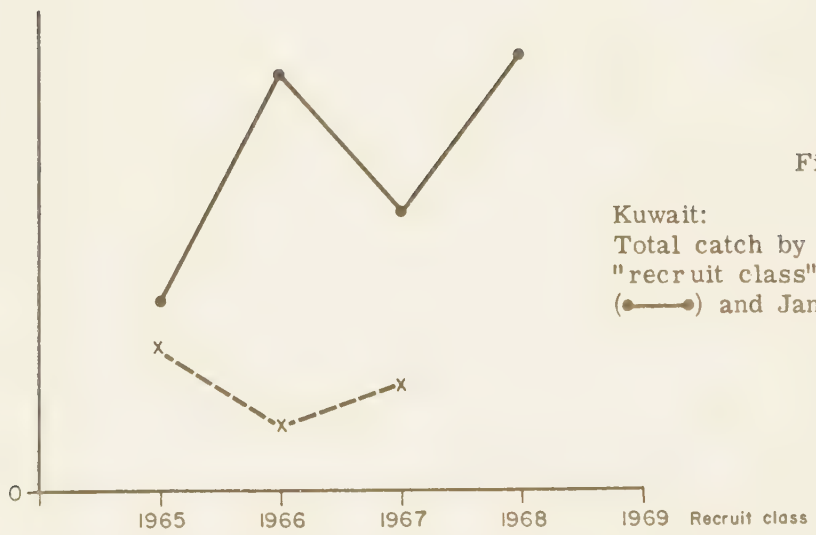

Figure 13.

Kuwait:
Total catch by weight of each
"recruit class" during July-December
(●——●) and January-March (x– – –x)

The time difference between April and August is such that it is unlikely that the very small shrimp caught in April-May are the very young ones of the same shrimp caught as 51-60 per lb in August, and these very small shrimp would therefore seem to be a different species. This has been confirmed by direct observations which showed that the catches of shrimp of more than 60 per lb contained very few young ones of the bigger species but consisted mainly of another, small, and as yet unidentified, species of shrimp (E. Petersen personal communication). Some large specimens of these species may be included in the shrimp of size gradings 41-50 and 51-60 per lb.

Figure 11 includes a graph showing the seasonal variation of the small shrimp of more than 60 per lb. Detailed data on these sizes were incomplete, and the graph includes the quantities of unsorted head-on shrimp (converted to tail weight) which were reported as mainly consisting of small and very small shrimp.

If the data are grouped for the months July-June, in the same way as done for Iran, each group contains most of the catches of one recruit class of the larger species of shrimp from the moment they reach a size of about 60 per lb. till they have grown to the largest size, but contains also a large amount of shrimp of the small species, mostly smaller than 60 per lb. and caught in April-June. Because nearly all bigger shrimp disappear from the catches in April, the catches from July-March will contain most of the large species shrimp of one recruit class from the size of 60 per lb onward, and include relatively little of the small species.

Figure 12 demonstrates the total catch, number of boat-months and catch per boat per month for each of the seasons July-March since 1965. Figure 13 shows the quantity of each "recruit class" caught in July-December and in January-March.

The increase in fishing effort has been accompanied by a rise in the catches in season July 1966-March 1967 but a decrease again in season July 1967-March 1968. The catch per boat per month has fallen greatly in this period. Figure 13 shows that the drop in the catch in season 1967-68, which is the catch for recruit class 1967, is due to the low catch in the period July-December. In order to identify the cause of these low catches, figure 14 gives the catch per boat per month in each of the periods January-March, April-June, and July-December, per calendar year, which represent the catches of medium and large shrimp of the previous year-class, the catches of the very small shrimp and the catches of the shrimp larger than 60 per lb of the same year's year-class, respectively. It appears from these graphs that the catch per boat per month in each of these periods in 1967 has been lower than in the corresponding periods of both 1966 and 1968, when the total effort was in the one case lower and in the other case higher than in 1967. This would suggest that the catchability of all shrimp has been low throughout 1967, and that this contributed to the low January-March catches of recruit class 1966 as well as to the low July-December catches of recruit class 1967. If this is taken into account in studying figure 13, the fishery off Kuwait would seem to give the same picture as that off Iran, that the increase in fishing mortality exerted on the shrimp has led to greater catches in the first part of the fishing season on a new recruit class and to lower catches later in the season (January-March). It has been reported that whereas most of the catches in 1965 and 1966 have been made in and around the Kuwait Bay, the catches on these grounds were low in 1967 and the fleet spread all over the Kuwait area. In 1968 the fleet moved still further south towards the Kuwait border and the Neutral Zone and it is particularly in this southern area that catches of large shrimp were made.

All this evidence together indicates, as in the case of Bushehre fishery off Iran, that the fishery off Kuwait has had a substantial effect on the stocks and that therefore the fishing mortality in the last years constitute a substantial part of the total mortality, with respect to the large species of shrimp (probably Fenaeus semisulcatus, the same species as is predominant in the other parts of the Gulf).

The total quantity caught of the small species is still relatively small (1/5 to 1/7 of the total weight of the catch) and does not yet show a decline in the total catches or catch per boat per month.

Figure 15 demonstrates the numbers of shrimp of the large species caught per size group (size groupings by gram tail weight). The low left-hand side of the line for the season July 1965-March 1966 is partly caused by the fact that relatively little fishing took place

Figure 14. Kuwait: Shrimp
Variation in catches between calendar years
●——● January-March
○—·—○ April-March
x– – –x July-December

Figure 15. Kuwait:
Size composition (numbers per gr. tail weight) of shrimp from the Kuwait area (●——●) July 65 - March 66; (x– – –x) July 66 - March 67; (○—·—○) July 67 - March 68. Shrimp over 60 per lb not included.

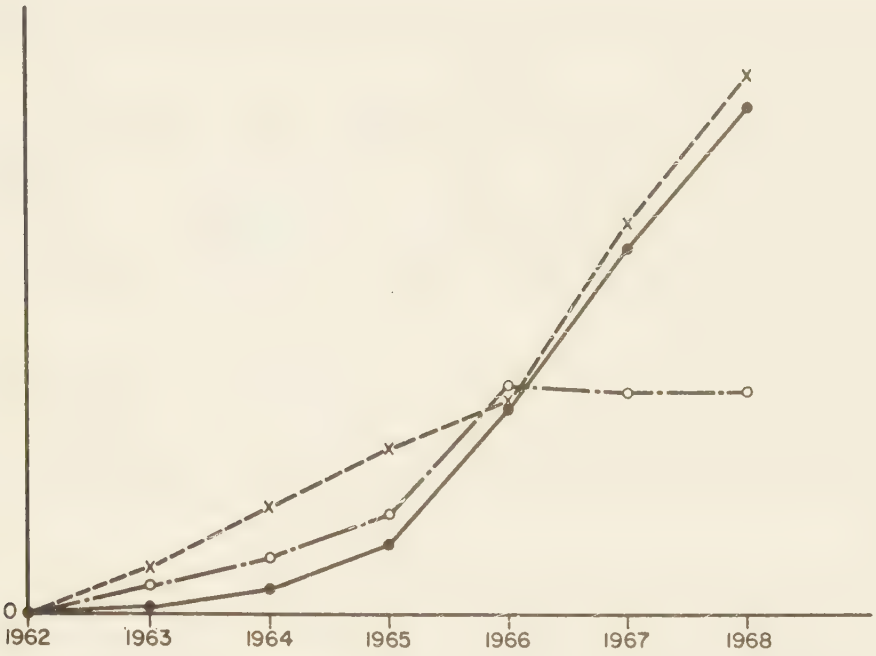

Figure 16. Shrimp fishery off Saudi Arabia (including Bahrain and Qatar). Number of boats (x——x), total catch (●——●) and catch per boat (○——○) per calendar year

in July-August 1965. The right-hand part of the line for the season July 1966-March 1967, and the left part of the line for season July 1967-March 1968, are possibly somewhat low due to low catchability of the shrimp in the calendar year 1967, as discussed above.

Taking all this into account, the curves do anyway show that the higher catches of small shrimp in the last two seasons were accompanied by smaller catches of big shrimp than those in the season 1965-66. This would be in accordance with what would be expected if fishing catches a substantial part of the stock. It should, however, be mentioned that the data for July-December 1968, even though they do not cover the whole season July 1968-March 1969, already suggest that the proportion between the shrimp of 10-15 gr and those of over 15 gr tail weight is similar to those of season 1965-66 rather than to the later seasons, in spite of the relatively high fishing effort in 1968. This may have been related with the shift of the fishery towards the south.

The data used in this section are not complete and do not include some of the catches and effort in the area. Also some 1968 data were provided for the Kuwait and the Saudi Arabian area together, which could not be separated in this analysis and have been included in the Kuwait data. This may partly have been the cause of some inconsistencies in the results. The data have also been affected by changes in the distribution of the fleets, and furthermore there seem to occur rather important changes in catchability of the shrimp in certain years.

Taking all these considerations into account, the available data do not provide as clear a picture as that of the fishery in the Iranian-Bushehre area. It seems fairly clear, however, that the fishery has had a substantial effect on the stocks of the large shrimp species in the major part of the Kuwait area and such data as are presently available do suggest that the level of maximum yield of these stocks may well have been reached in this area. If this conclusion is correct, this yield would appear to be of a level of somewhat over 3 million lb per recruit class of shrimp (and hence per fishing season), with fairly substantial fluctuations from year to year due to variations in natural circumstances.

As stated above, the available data on the catches of the small species of shrimp did not yet show any effect of fishing, and it could well be that the stocks of these species could support a catch rather higher than the level of roughly 700,000 lb (tail weight) reached in the last few years.

4.5.3 The fishery off the coast of Saudi Arabia (including the grounds around Bahrain and Qatar)

Figure 16 gives a picture of the total catch, the number of boats, and the average catch per boat per year in the area along the Saudi Arabian coast, including the fishing grounds around Bahrain and Qatar. A number of boats, belonging to companies established in other countries, have been fishing in this area for part of the year 1968 only. This has been taken into account in determining the total number of boat-years. However, the figures used in the graph are approximate figures only. They show that after an initial increase in the number of boats and in the catch and the catch per boat per year, until 1966, the number of boats increased further and the catch per boat remained about constant, so that the total catch increased proportional to the number of boats.

The seasonal variation in the catches, demonstrated in figure 17 (total catches) and figure 18 (catches by size group), is similar to that in the Iranian and the Kuwait area. Although the curves for all sizes of more than 25 per lb have their mode in October (except for head-on shrimp), the general shape of the curves clearly indicate the shift towards the later months with increasing size. They show that the autumn peaks in the catches of each size group appear one to two months later than in those of the same size groups off Iran. Again, the catches during the months from July of one year till June next year will consist mainly of the shrimp of one recruit class, which appears in the catches at a size of about 60 per lb by July-August. Unfortunately, detailed data of the shrimp catches by month and by size group in the Saudi Arabian area are available for not more than a part of the fleet, and cover the years 1967 and 1968 only. They, therefore, contain data from July-June of only one recruit class. It is thus not yet possible to compare the catches per recruit class at different levels of fishing, as was done in the analysis of the Iranian and the Kuwait fisheries. The curve for the head-on shrimp in figure 18 suggest that the species of

Figure 17. Saudi Arabia: shrimp.
Seasonal fluctuation in the total catches, by weight. Average 1967 - 68.

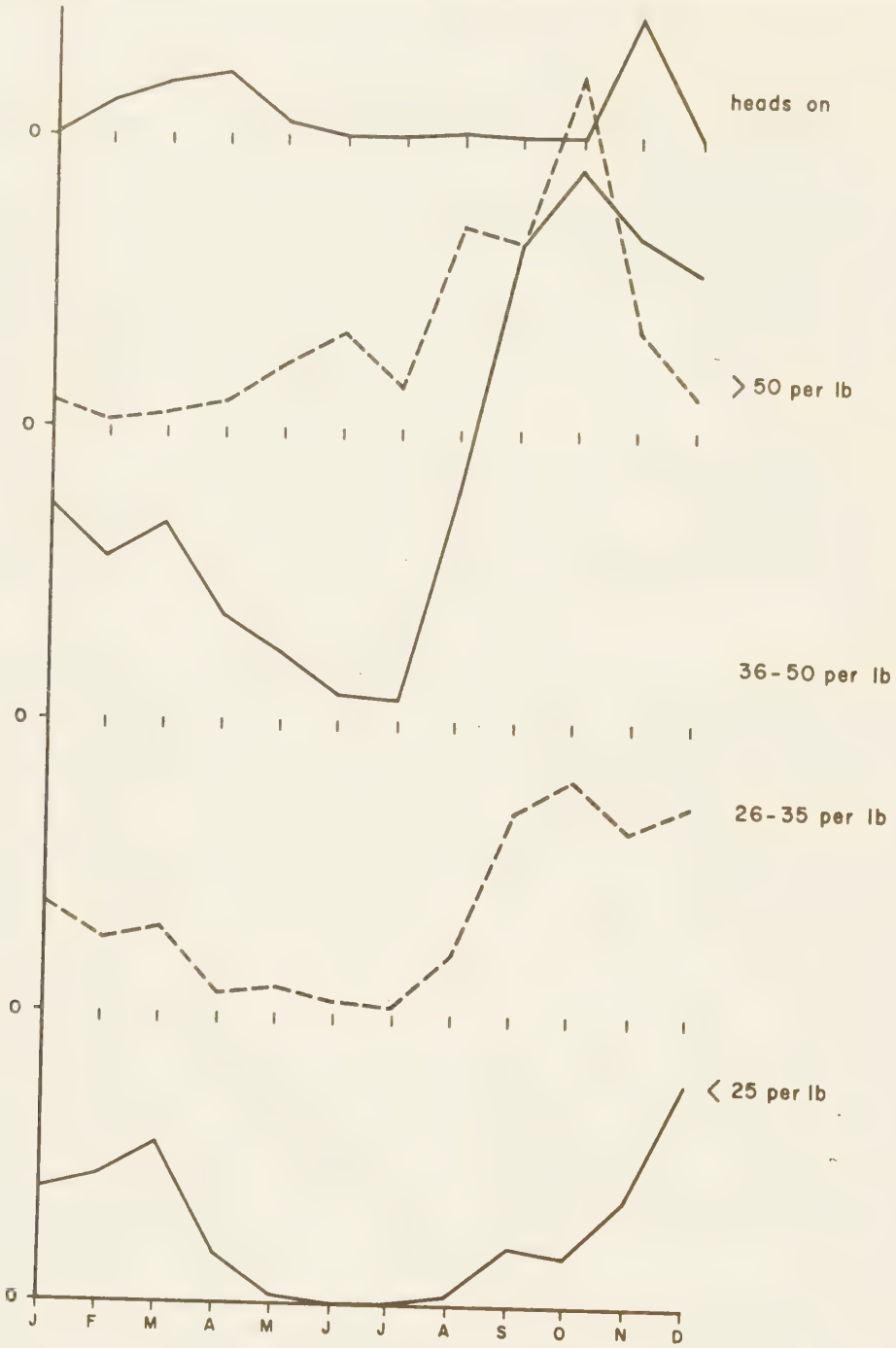

Figure 18. Saudi Arabia: Shrimp.
Average monthly catch per size category, by weight, per boat. Average 1967 - 68.

small shrimp caught off Kuwait in about April, is also caught off Saudi Arabia in small quantities in about the same period.

Figure 19 shows the size composition of the catches made in July 1967-June 1968, representing the catches of recruit class 1967. The slope of the right-hand side, and hence the proportion of large to middle sized shrimp in the catches in this area, appears to be more similar to the catches in the Iranian and Kuwait area in the last two years than to those in season 1965-66. This is also shown in Table 4, which gives the number of large shrimp caught (less than 25 per lb) as the proportion of the number of medium size shrimp caught (between 26 and 35 per lb), for each of the areas and seasons separately. This proportion would be expected to decrease with increasing fishing effort. The highest proportion given in the table is observed in the Kuwait area in season 1965-66, at the time when the expansion of the fishery started. The figure for the same season in the Iranian area is considerably lower, but in this area the fishing intensity had already reached a high level. The figures for the seasons 1966-67 and 1967-68, in which fishing was again at a higher level, were below those for 1965-66 in both areas. (It should be remembered that in the section on the Kuwait area, the low catches in the year 1967 were suggested to be due to low catchability in that year. This would then be the cause of the relatively low figure for season 1966-67 and the rather high figure for season 1967-68 in Table 4.) The proportion shown for Saudi Arabia is similar to the proportions in the other areas where fishing was intensive, in particular to those on the Iranian coast.

Table 4 - Numbers of large shrimp (> 25 per lb) caught, expressed as proportion of the numbers of medium size shrimp (26-35 per lb) in the catches

Country	1965-66	1966-67	1967-68
Iran	0.66	0.45	0.54
Kuwait	1.24	0.22	0.80
Saudi Arabia			0.53

This is no real proof that fishing in the Saudi Arabia has exerted the same effect on the stocks as in the other areas, because the size composition of the catches depends not only on the intensity of fishing, but also on the distribution of the fishing fleet and of the various size groups of shrimp, and on other factors.

The data of the total catch, number of boats and catch per boat shown in figure 16 suggest that the increase in the fishery has not affected the catch per boat, and hence they might indicate that the shrimp stocks on the Saudi Arabian side of the Gulf are still underexploited. The data on the length composition of the catches, however, even though they do not provide a real proof that fishing in this area already affects the stocks, may still be taken as a warning that the statistics of figure 16 should not be accepted at their face value. Very little is known about the increase in the efficiency of the boats in recent years, about the exploitation of new grounds within the area, etc.

A more satisfactory evaluation of the size of the stocks in this area and of their state of exploitation will have to wait until more data become available. The results of the forthcoming seasons will provide valuable information for this purpose, but it would be particularly important if also more complete and detailed data of past seasons, including those before 1967, could be obtained.

5. SUMMARY OF THE CONCLUSIONS ON THE STATE OF THE SHRIMP STOCKS AND THEIR EXPLOITATION, AND DISCUSSION OF POSSIBLE MANAGEMENT MEASURES

Section 4 has given several arguments which indicate that the shrimp fishery in the Gulf exerts a substantial effect on the shrimp stocks, and hence on the catches. The analysis shows that, most likely, the fishery in the Bushehre-Dayer area has reached a stage where

Figure 19. Shrimp size composition (number for each gr. tail weight) of shrimp from the Saudi Arabian area, July 67 - June 68.

increase in the fishing effort, e.g. in the number of the vessels, will not increase the total catch, and will, therefore, result in a further decrease in the average catch per vessel. It is even possible that it would result in a decrease in total catch as well. A limited reduction in the fleet in this area would seem to result in a total catch which is not much lower than, and perhaps equal to, the catch to be obtained with the present fleet, and would lead to somewhat higher catches per boat. Furthermore, the average size of the shrimp in the catches would somewhat increase.

The increase in fishing in the period under observation has had the result that of the new recruit classes of shrimp entering the fishery each year a larger and larger proportion has been caught in the first six months of the season, leaving less and less shrimp to grow and to survive into the second six months of the season (January-June). Observations on the development of the ovaria indicate that whereas some spawning may take place throughout the year, the main spawning seems to occur in spring or early summer (Keyvanfar personal communication) and the reduction in shrimp surviving till this period must, therefore, also have resulted in a considerable reduction in the spawning potential of the shrimp stock. Although up till 1968 the data do not show that the recruitment of young shrimp has declined as a consequence of the decrease in the spawning potential, the risk of such an effect occurring, when the spawning potential declines below a certain level, should not be neglected.

The same considerations as given above for the Iranian area are likely to be valid also for the area off Kuwait, even though the data for the latter area do not give as clear a picture as those for Iran. The fact that the data are less consistent for the Kuwait area seems to be related to greater annual variations, possibly due to the hydrographic circumstances in this region, and to greater changes in the distribution of the fleet. The data for the Saudi Arabian side of the Gulf are contradictory and are too limited to draw any definite conclusions, but the possibility should not be excluded that in this area too the optimum level of production is not far above the present level.

The present conclusions had to be based on a series of rough and approximate data covering the period since the start of the fishery until recent years, and in addition on a very limited series of detailed data for the last years, and they may, therefore, be subject to modifications if more data would become available. More detailed information on the earlier years would contribute considerably to the reliability of the analysis.

According to recent reports, the fishery in July-August 1969 has been extremely poor in several parts of the Gulf. It is too early to determine whether this is due to poor recruitment as an effect of the decline in spawning potential, or to environmental factors, or to a combination of both. Whatever the cause for this poor fishing, the above analysis has shown that it may be timely to consider what would be the effect on the fishery of possible management measures.

The effects of changes in fleet size have already been mentioned above. Another possible measure concerns the protection of the young shrimp. Whether such protection will lead to a greater weight of the catch depends on the average weight of an individual of these young shrimp, on the probability of their being caught later, and on the average weight when caught at this later time. Both the average weight of an individual young shrimp, and of the shrimp when caught later, can be easily determined from the present catches. If the shrimp smaller than 50 per lb were not caught, with an average weight per individual of about 7.9 gr (tail weight), at a fishing rate such as occurring at present on the Iranian coast these shrimp would be caught later at an average weight of about 14.1 gr. In order for the catch by weight not to decrease, at least $\frac{7.9}{14.1}$, or 56%, of the shrimp released as more than 50 per lb should be caught later. In the same way, shrimp smaller than 40 per lb, weighing on the average about 9.1 gr, and if protected until the size of 40 per lb, caught later at an average weight of about 15.8 gr per individual, would require capture of more than $\frac{9.1}{15.8}$ or 58% of the numbers of shrimp protected as young shrimp (data based on the Iranian catches in season 1966-67 and 1967-68, for the total catch by weight not to decrease.

The probability that a shrimp protected as a young one will, in fact, be caught later is equal to the fraction of these young shrimps surviving until the new size limit, multiplied by the exploitation rate, the fraction which the fishing mortality contributes to the total

mortality. In order to capture 55-60% of the young shrimp, protected by the size limit, at a later age, the present exploitation rate must be higher than 60%, to allow for the natural mortality before the shrimp reach the new size limit. The available data are not sufficient, however, to determine whether the present fishing mortality has reached such a level. For this purpose, more detailed data of the effort and of the monthly catches by size grading for the earlier years of the fishery would be of very great value.

Furthermore, it seems that sometimes rather large quantities of young shrimp, smaller than 70 per lb, are caught and discarded at sea. Many of those will not survive this treatment. These shrimps have not been included in the above calculations. Any protection of this category will result in greater catches of the larger shrimp. If the number of young shrimp destroyed in this way is substantial, the protection of young shrimp, smaller than 50 or 40 per lb, as discussed above, may already lead to a higher weight of the total landings at an exploitation rate rather lower than calculated above. In terms of value of the catch, an advantage of protection of young shrimp might even arise at a still lower exploitation rate, due to the higher price paid for large shrimp than for small ones. Hence, there certainly is a possibility that the protection of small shrimp will result in a higher weight and/or value of the catch at the present level of fishing. Data on the amount discarded would help to get further insight in this problem.

Even though it cannot yet be determined whether the total weight of the catch would increase or decrease as an effect of the protection of small shrimp, it should be realised that such protection would anyway result in increased catches of the larger size gradings of the shrimp, and in some increase of the shrimp surviving until maturity and spawning.

If any protection of these young shrimp is being considered, it should be done in such a way that not only landing of these small ones is being prevented, but also their actual catch. This might possibly be achieved by prohibiting fishing in the period of the appearance of the young shrimp in the catches, e.g. by closing the month of July for fishing in the area off Iran. In this area, the catches in July consist very predominantly of the shrimp of more than 50 per lb, and of a certain amount of shrimp between 40 and 50 per lb. In the other areas similar periods are found in about August.

Iran has recently introduced a closed season in May and June, for the protection of spawning and baby shrimp. Apart from the question whether this is the peak period of spawning, it is also a period in which the fishing activity usually is low. The beneficial effect of this measure on the spawning stocks is, therefore, of a limited nature, but the immediate losses in the catches are also small. Closure of the month in which the young shrimp appear in the catches in large quantities, and in which fishing usually is intensive, would probably have a greater effect on the spawning stock, but, as said before, it is not known whether this might lead to a somewhat smaller or a greater total weight of the catch. It has been explained above that the need for protection of the spawning stock has not been established, but recent developments, including the continued expansion of the fleets, would seem to make it advisable to take into account the possibility that such need might arise, if it does not already exist.

One question remains to be mentioned. The fisheries in the three main areas have been discussed separately in this study, but in how far are the stocks in these areas dependent upon each other? It is not possible on the basis of the present data to draw any conclusions on the existence of separate populations of the main shrimp species <u>within</u> each of the three major areas distinguished in this report. The data for each of these areas separately, however, show the difference in the timing of the peak catches of each size group of shrimp between the three areas. This indicates that, once the young shrimp appear in a certain area, they remain in the same major area during at least a great part of their life, and the fishery in that area, therefore, depends upon that group of shrimp only. In this respect they can be considered as separate populations of shrimp. It cannot yet be decided, however, whether the young shrimp in one area have originated from the spawning of the parent stock in the same area, or the recruits originating from the parent stock in one area may spread over the various areas, in which case the recruitment in one area may also be affected by the spawning population in other areas.

Finally, it should be repeated that all the considerations in this section concern the stocks and catches of the large species of shrimp (probably all Penaeus semisulcatus).

The small species referred to in the section on Kuwait, which is probably also caught in small quantities on the Saudi Arabian side of the Gulf, and is possibly present on the Iranian side as well, is at present exploited to a limited extent only and might well be able to support larger catches.

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